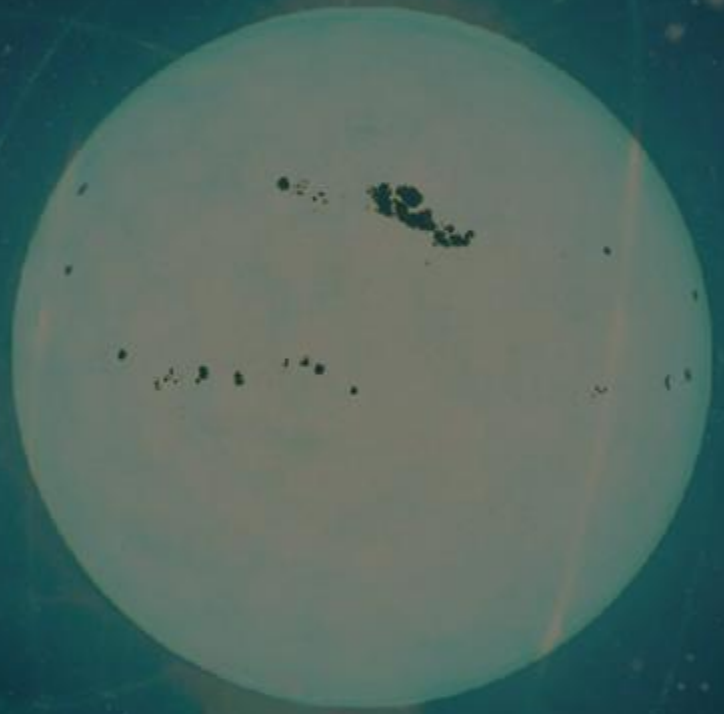
A LANDSCAPE OF MAIN SEQUENCE STARS ACTIVITY

Or "How to count spots on stars?"

Lucie Degott

PhD advisors: Frédéric Baudin (IAS), Réza Samadi (LESIA)

INTRODUCTION- WHAT IS A STAR ?



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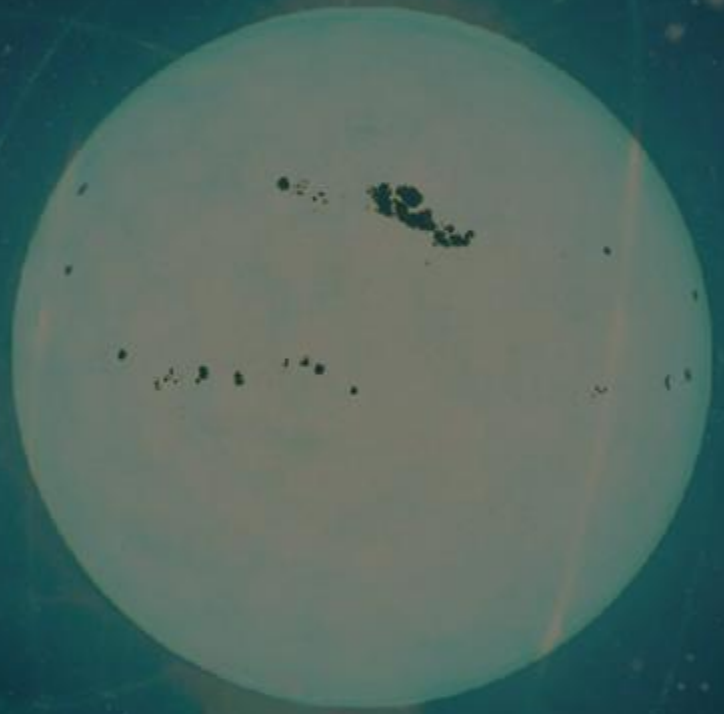
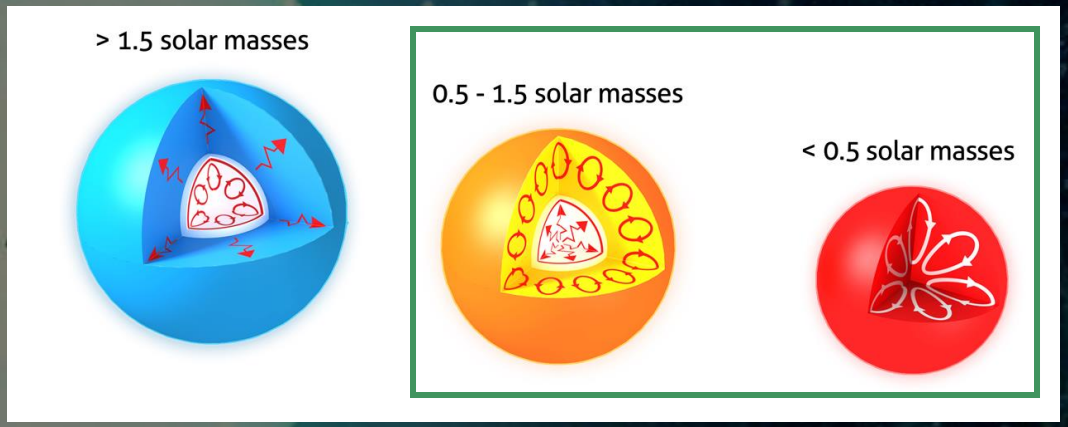
Answer 1 : A bright point in the night sky



INTRODUCTION- WHAT IS A STAR ?

Answer 1 : A bright point in the night sky

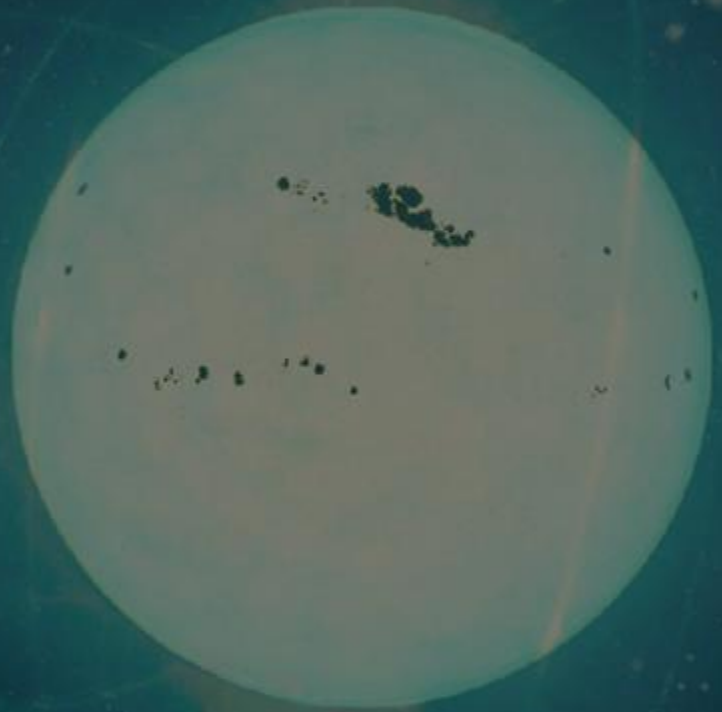
Answer 2 : A luminous astrophysical object at hydrostatic equilibrium capable of making fusion reaction.



Low mass stars

INTRODUCTION- WHAT IS A STELLAR ACTIVITY ?

Stellar activity : Variability due to magnetic phenomena on the surface of stars.



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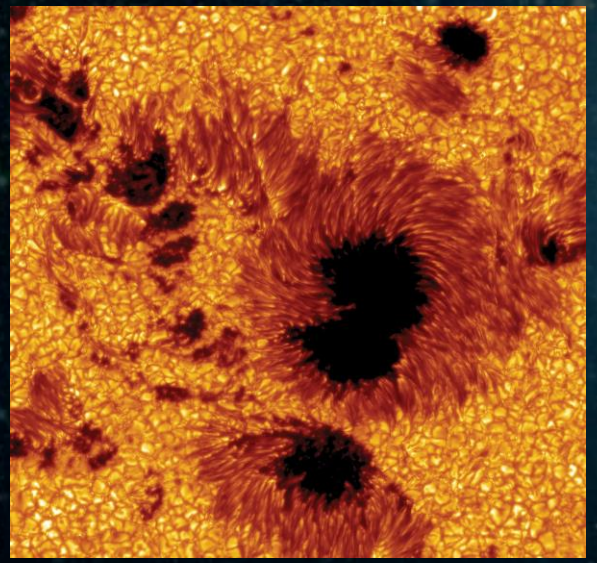
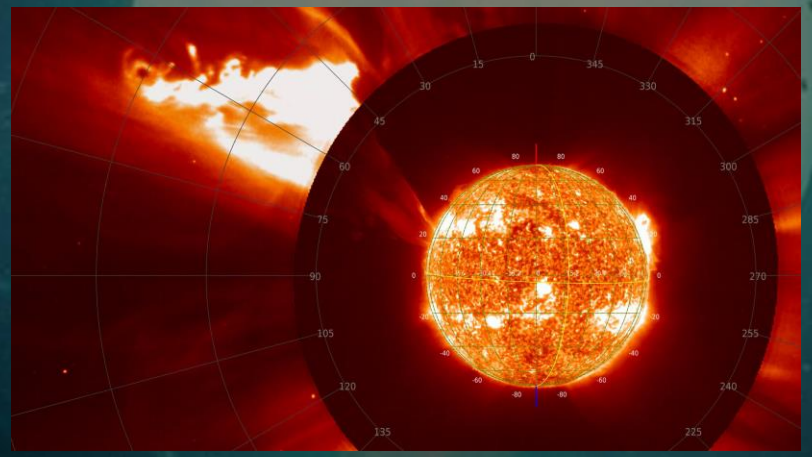
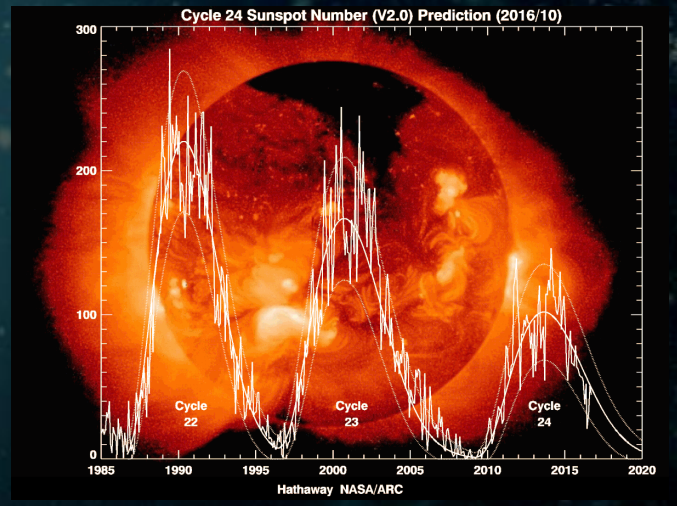


Sun spots/ active regions



Eruptions / flare



Solar cycle

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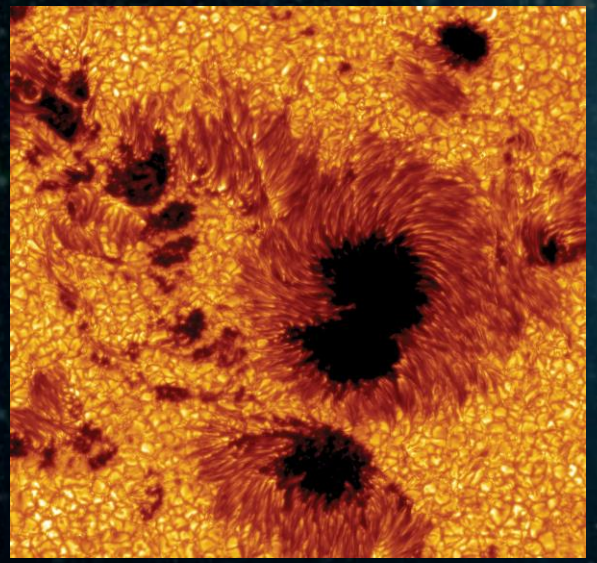

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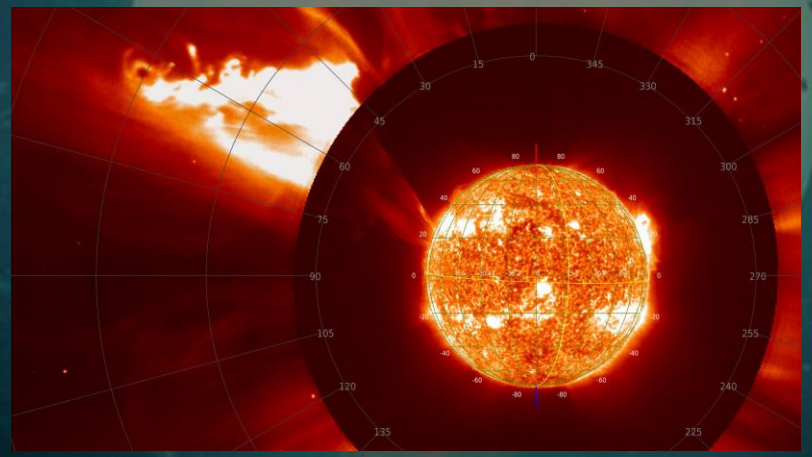

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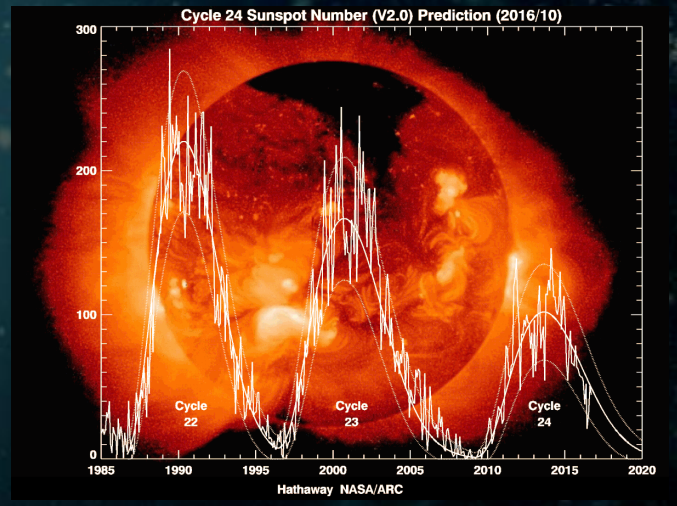
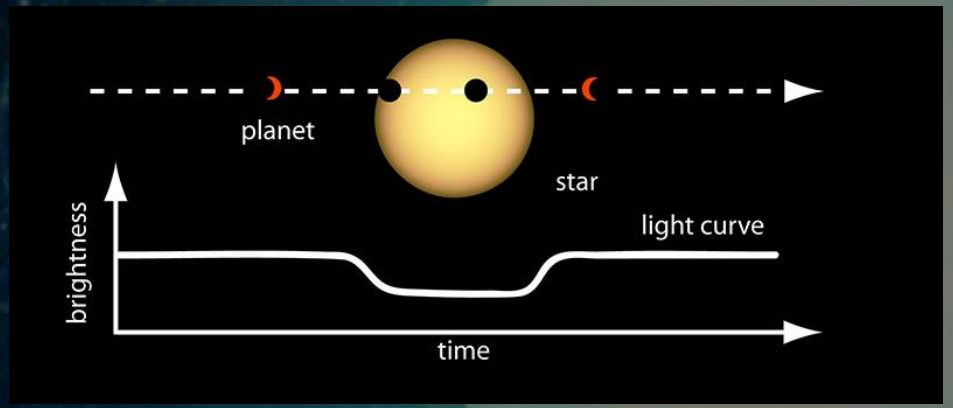
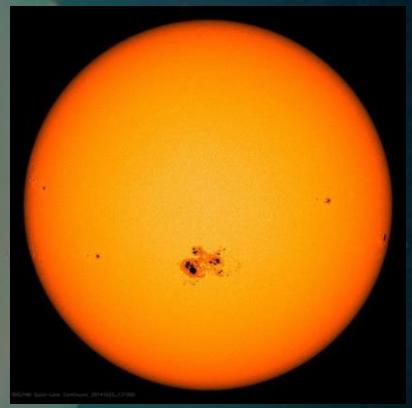


Solar cycle

WHY IS IT IMPORTANT TO STUDY STAR ACTIVITY ?

- **Improve the detection of exoplanets** and better understand the **interaction between stars and the planetary system.**





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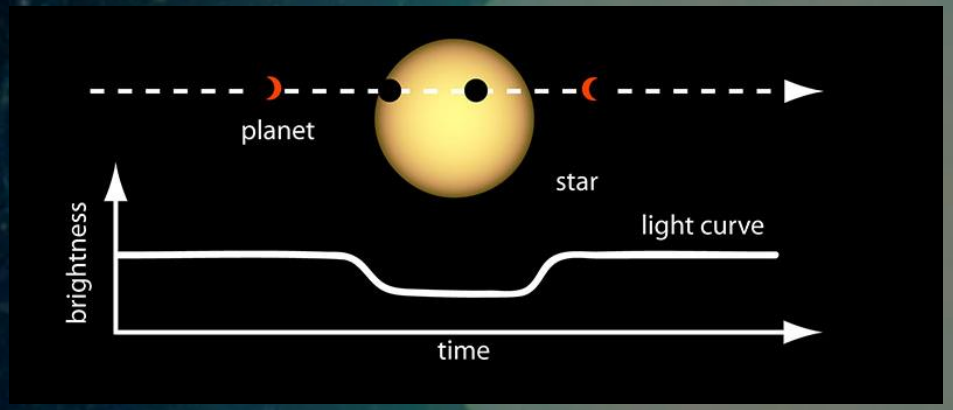
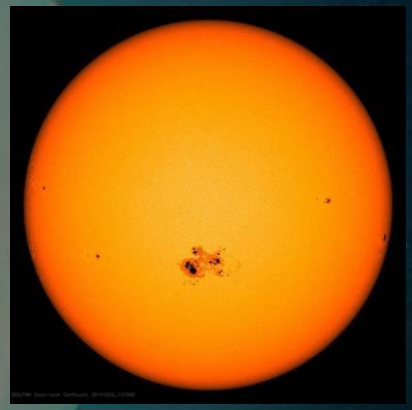
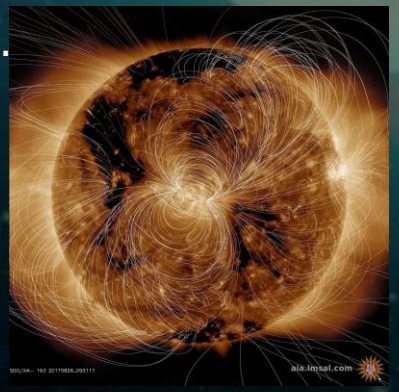
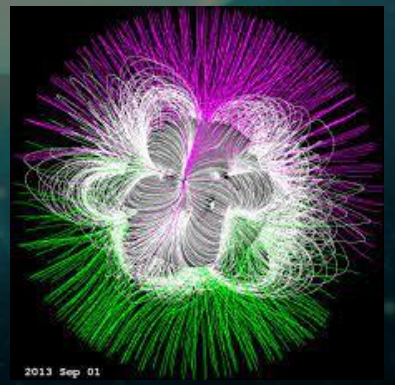




- Better understand the intern and extern **magnetic field structure** of the stars -> better **understand the dynamo effect** of the stars.





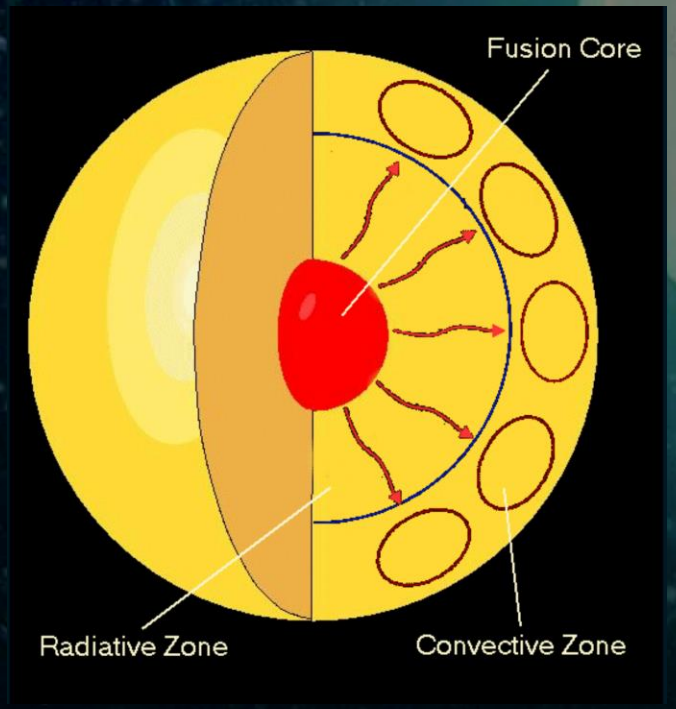
DYNAMO EFFECT

Definition: capacity of a magnetized fluid to maintain and/or amplify its magnetic field despite ohmic dissipation.

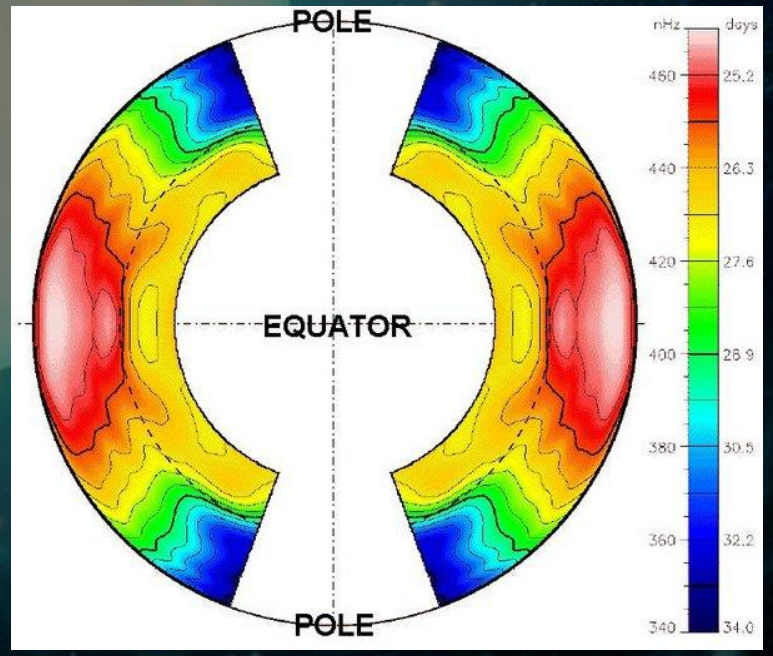
Translation : the effect that maintains the magnetic field of a star.

2 ingredients :

Convection



Differential rotation



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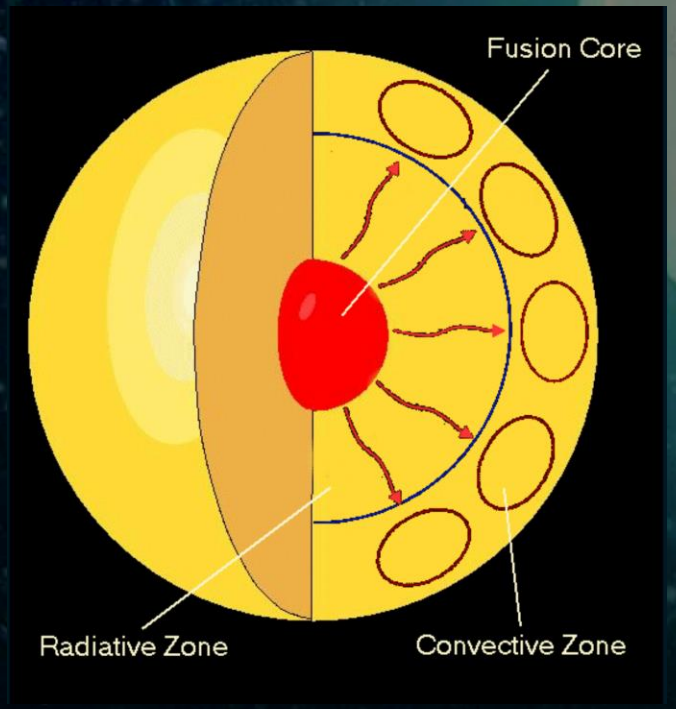

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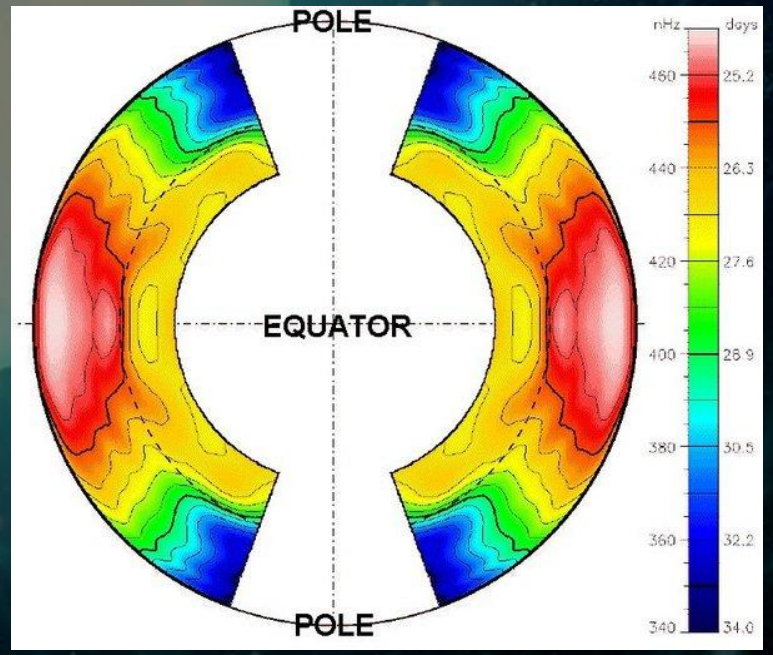

Rossby number :

$$N_{Ross} = \frac{P_{rot}}{\tau_g}$$

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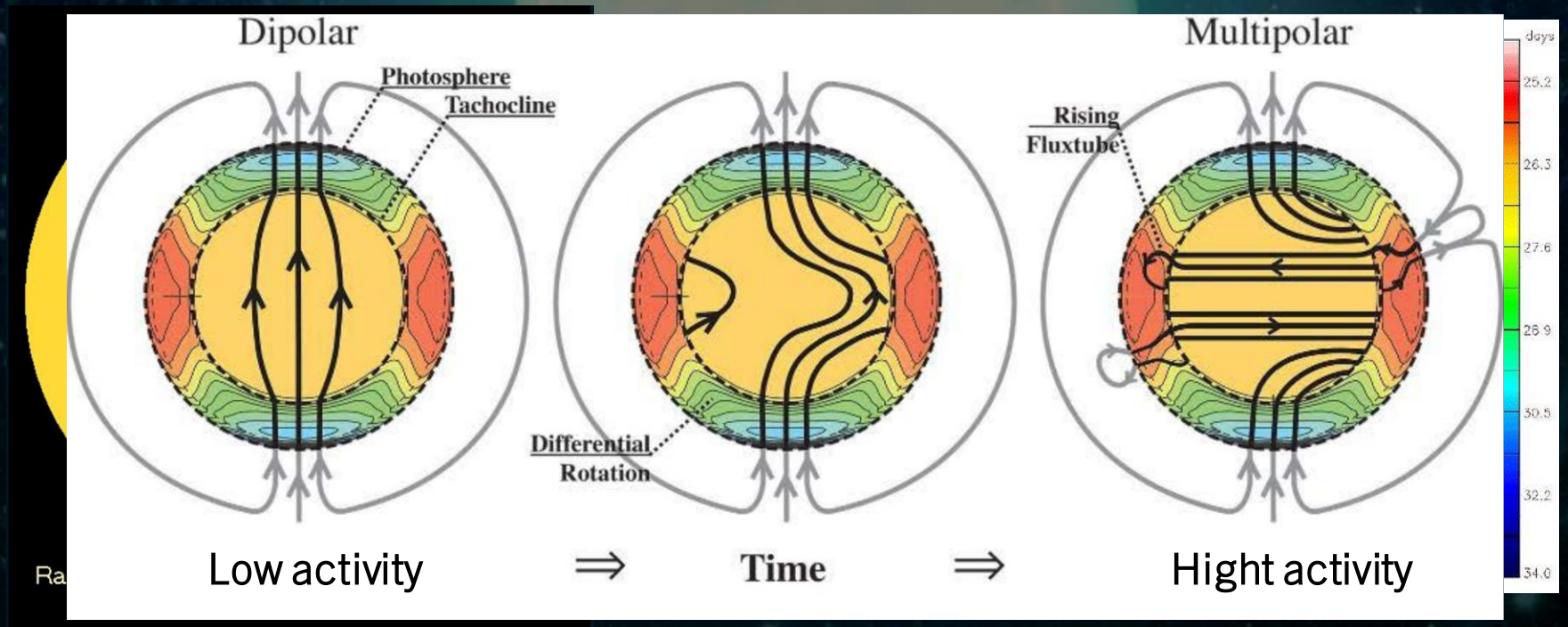

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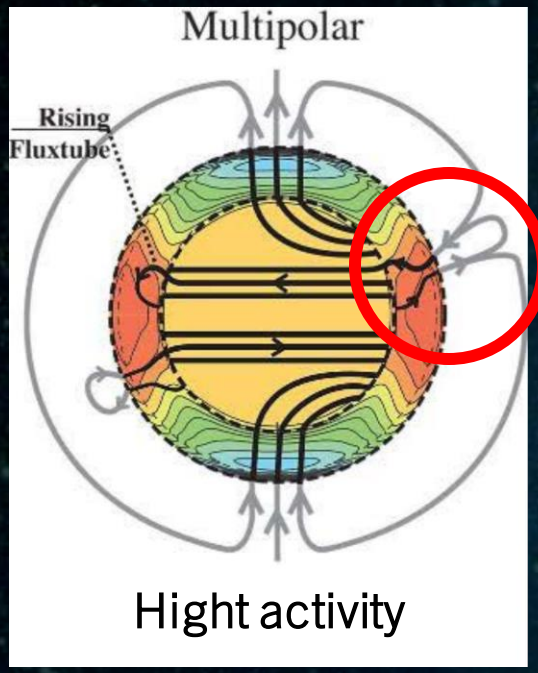
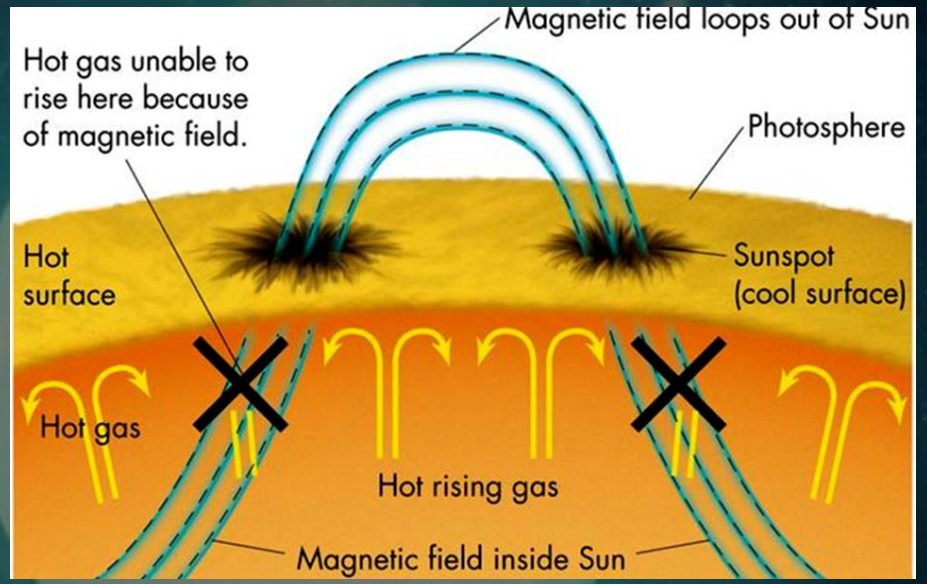
WHAT IS A SPOT ?



Hight activity



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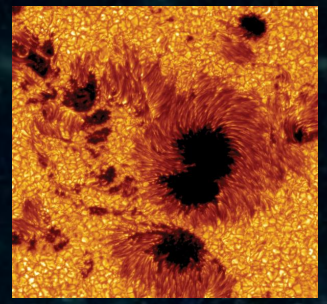

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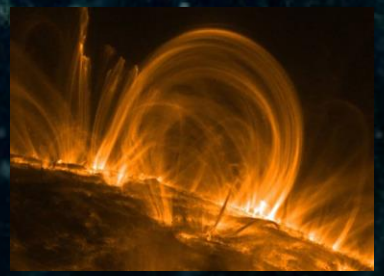
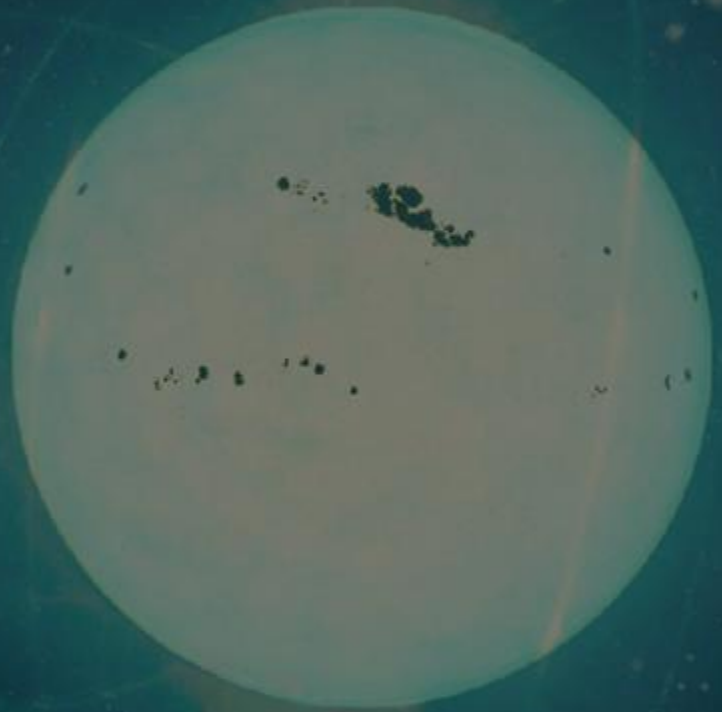


Coronal loop

→ Spots are magnetic activity tracers

HOW TO OBSERVE STAR SPOT ?



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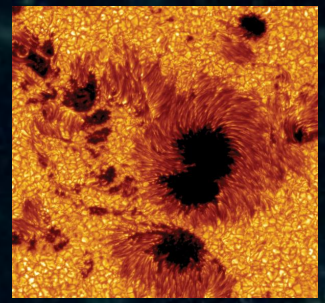

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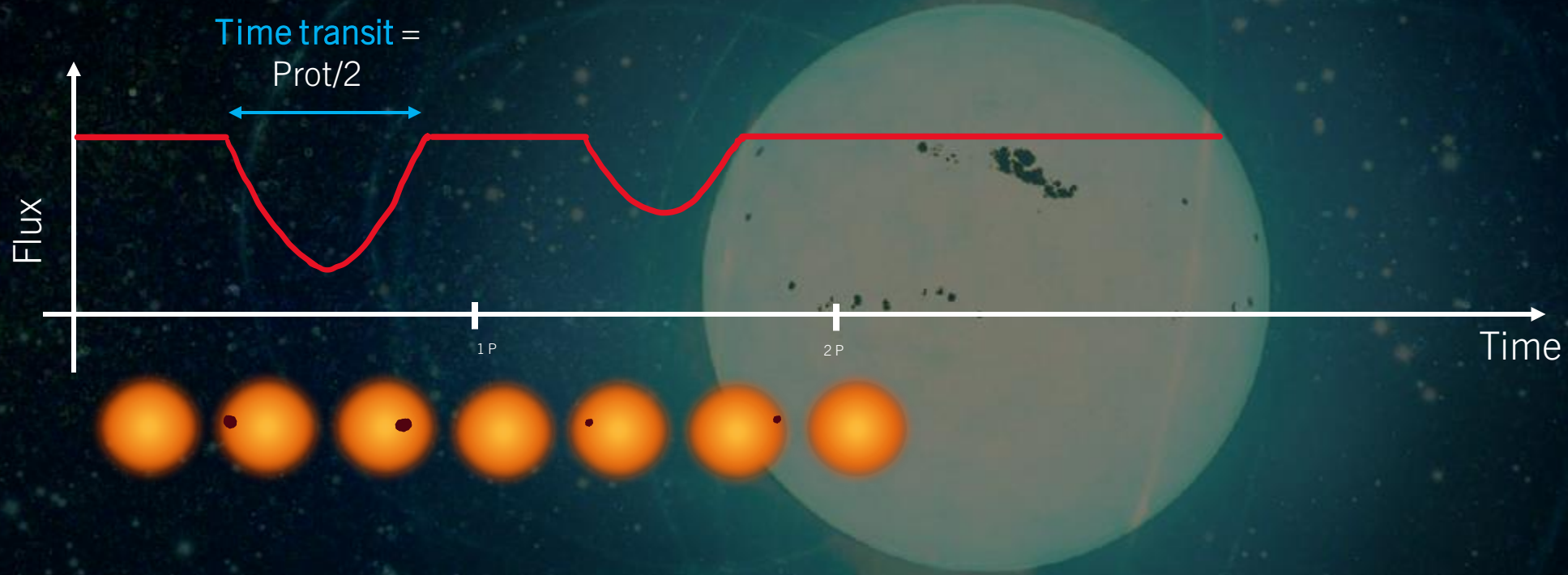

Light curve : evolution of the luminosity of an astrophysical object versus time.

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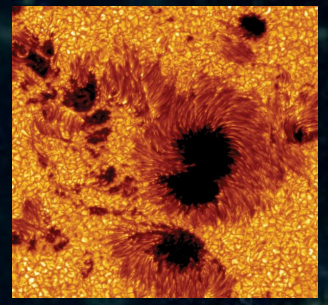

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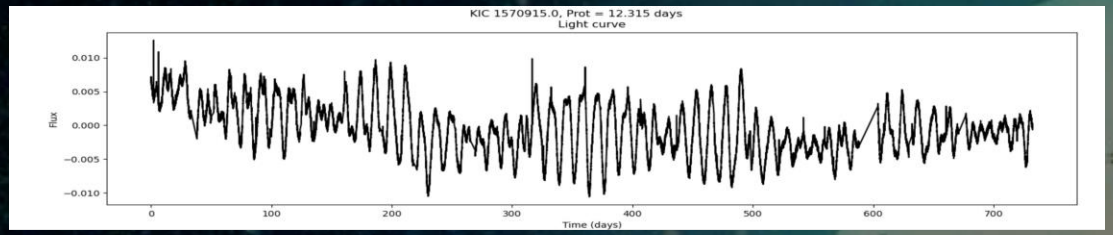
HOW TO OBSERVE STAR SPOT ?

Temporal domain



Is it possible to extract information about the spots ?

Problem : there is a lot of degeneracies in this problem.

- The obliquity of the star with respect to the line of sight
- The lifetime of the spots
- Its temperature
- Its size
- ...

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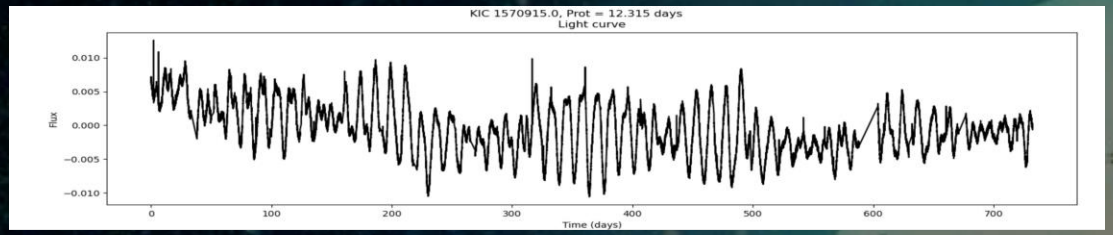

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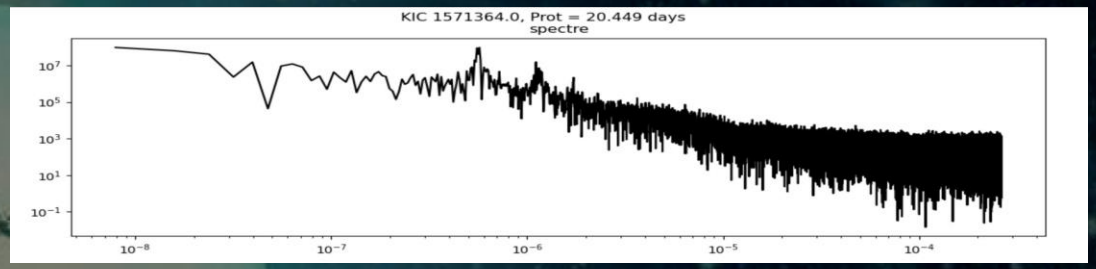


New approch : use the Fourier domain on a large sample of stars.

⟶ Extract mean informations instead of single properties of spots.

⟶ Analyse the trends that are showing up using a large number of stars

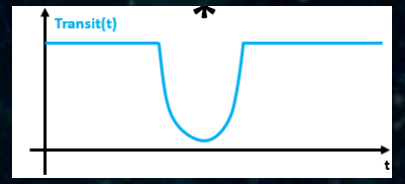
NEW APPROACH

Analytical approach gives 3 proxies :

- **The transit duration (Prot/2)**

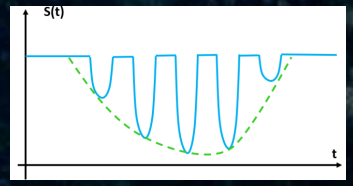
3 new “proxy” :

Transit proxy



- **The intrinsic evolution time spot**

Lifetime proxy



And an information about spot surface :

- **The spot coverage** in term of surface and temperature.

Coverage proxy

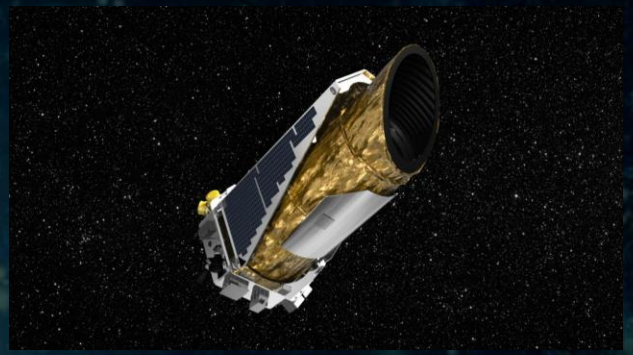
✓ Has been tested on simulations

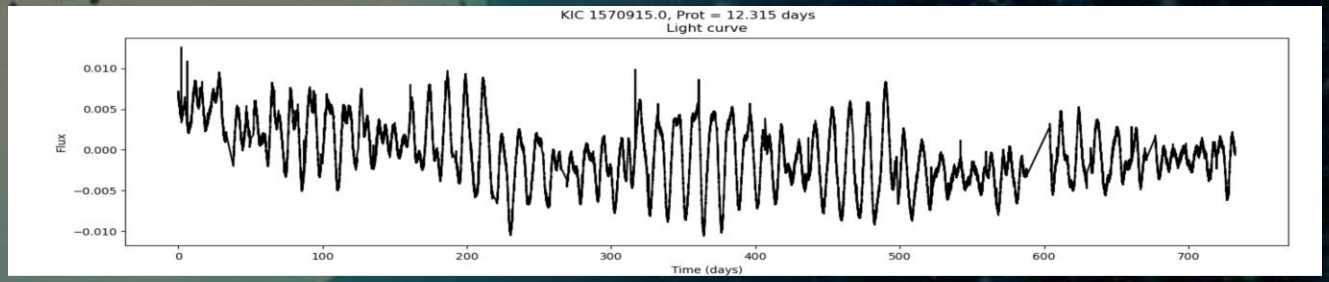
✓ Has been tested on solar data

KEPLER DATA

McQuillan et al. 2014 sample :

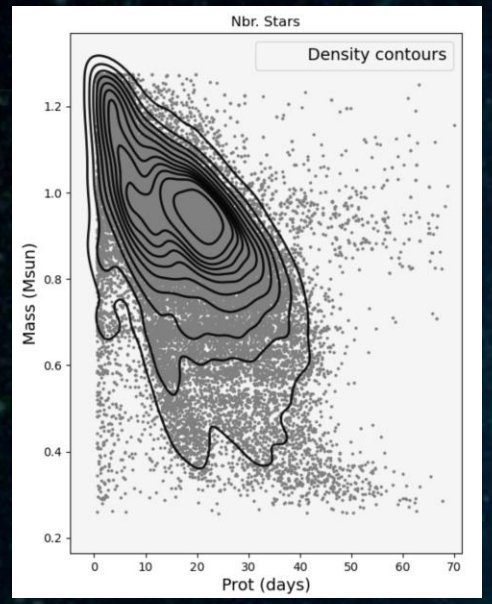
- 34 030 main sequence stars
- No exoplanets transits in the light curve
- Estimation of the rotation period
- Other parameters: Mass, Teff, log . . .
- 2 rotations regimes





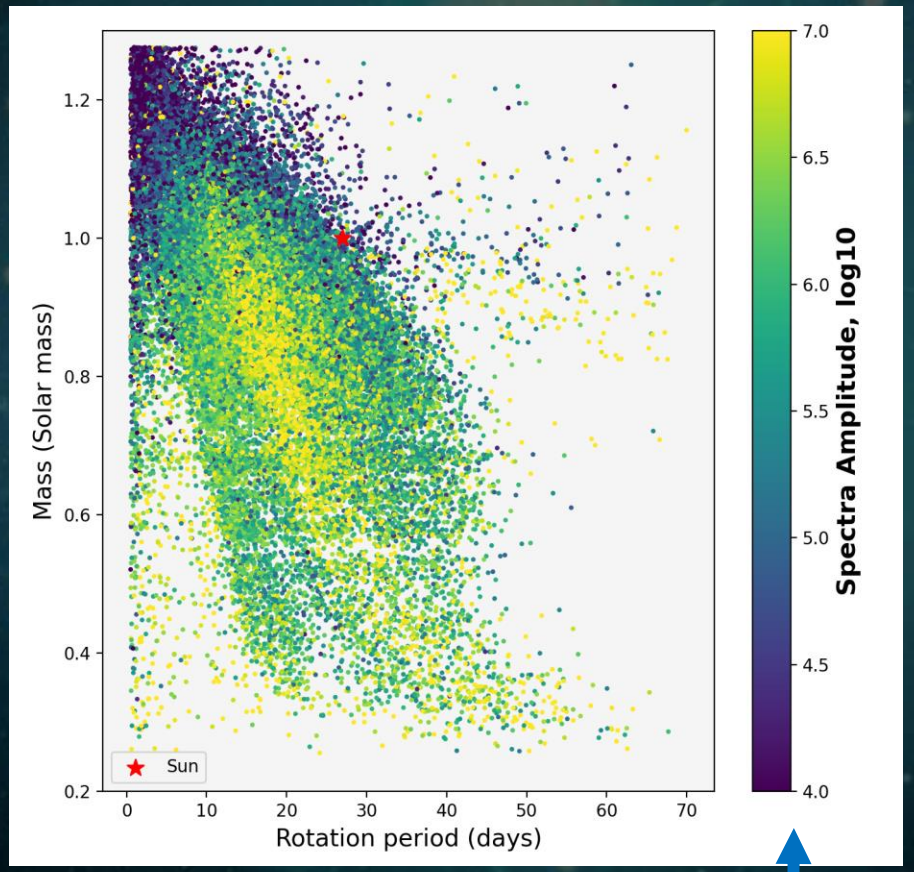
KEPLER DATA

Star density



Surface proxy

Lot of surface covered



Less surface covered

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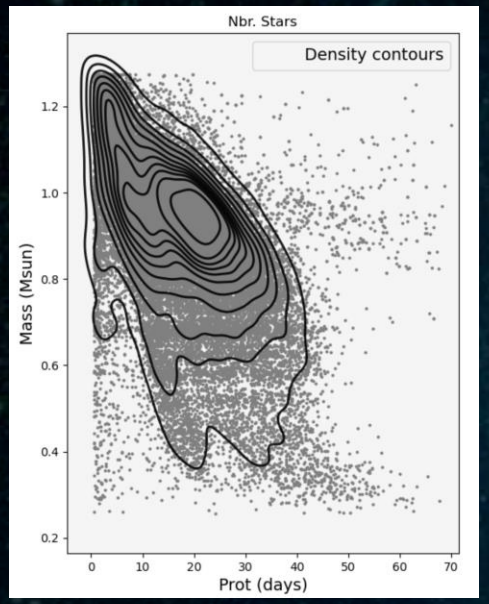

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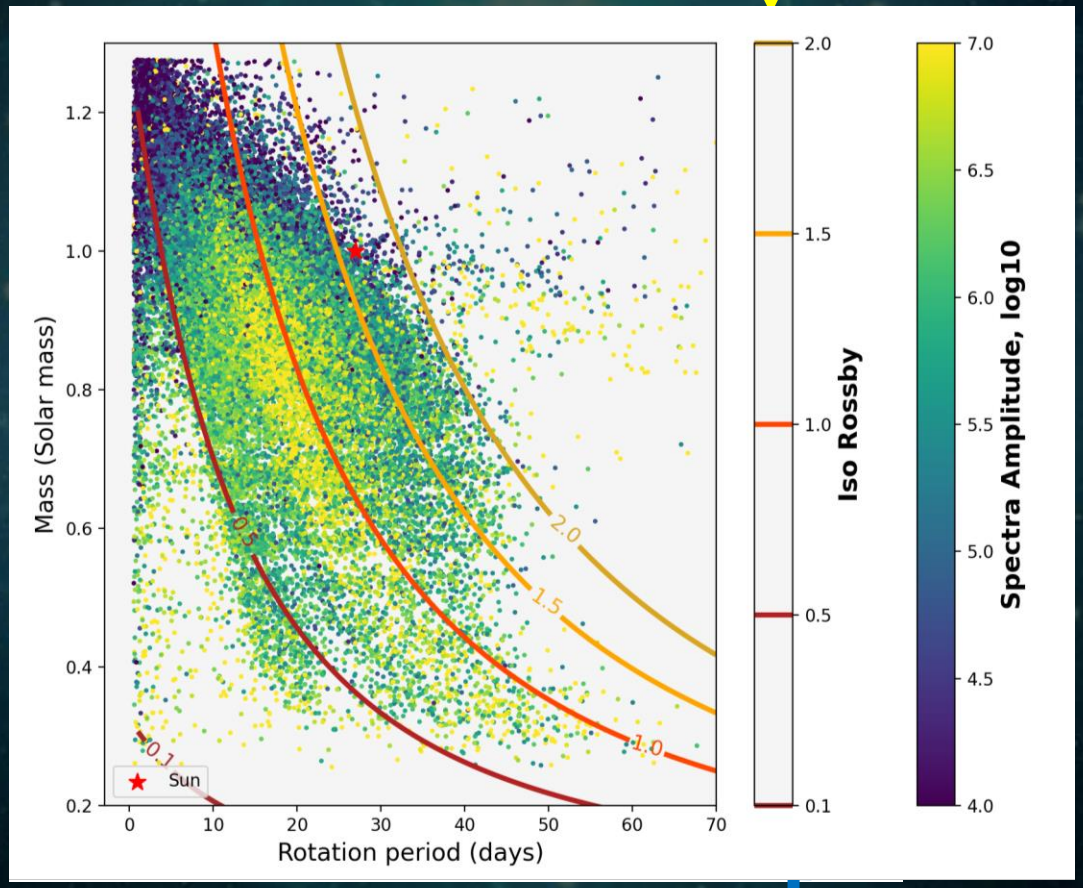

Less surface covered

Rossby number :

$$N_{Ross} = \frac{P_{rot}}{\tau_g}$$

Differential rotation

Convection

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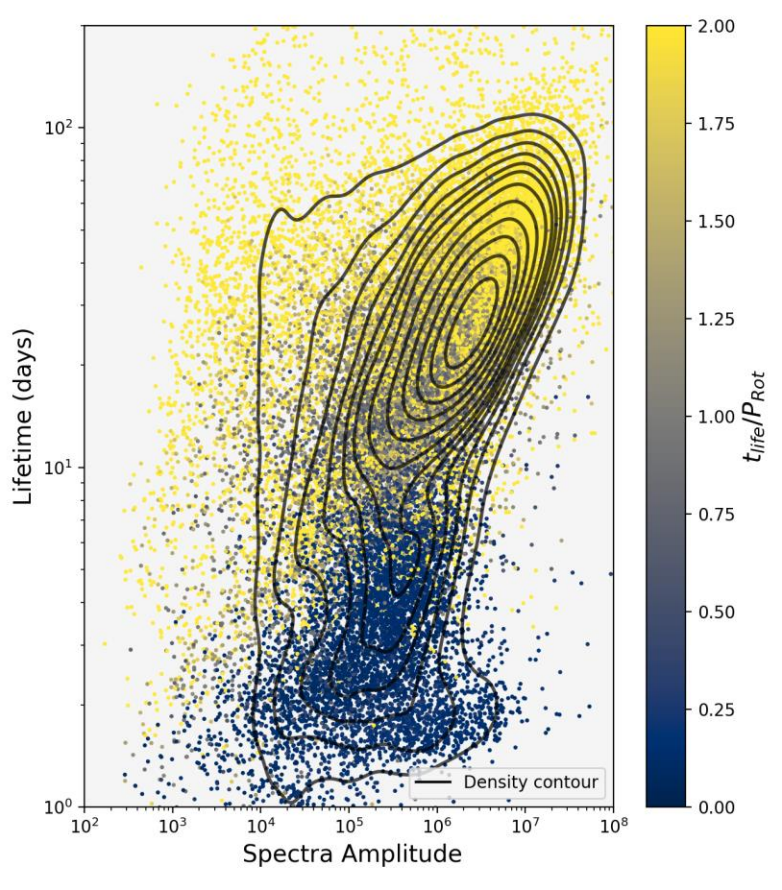


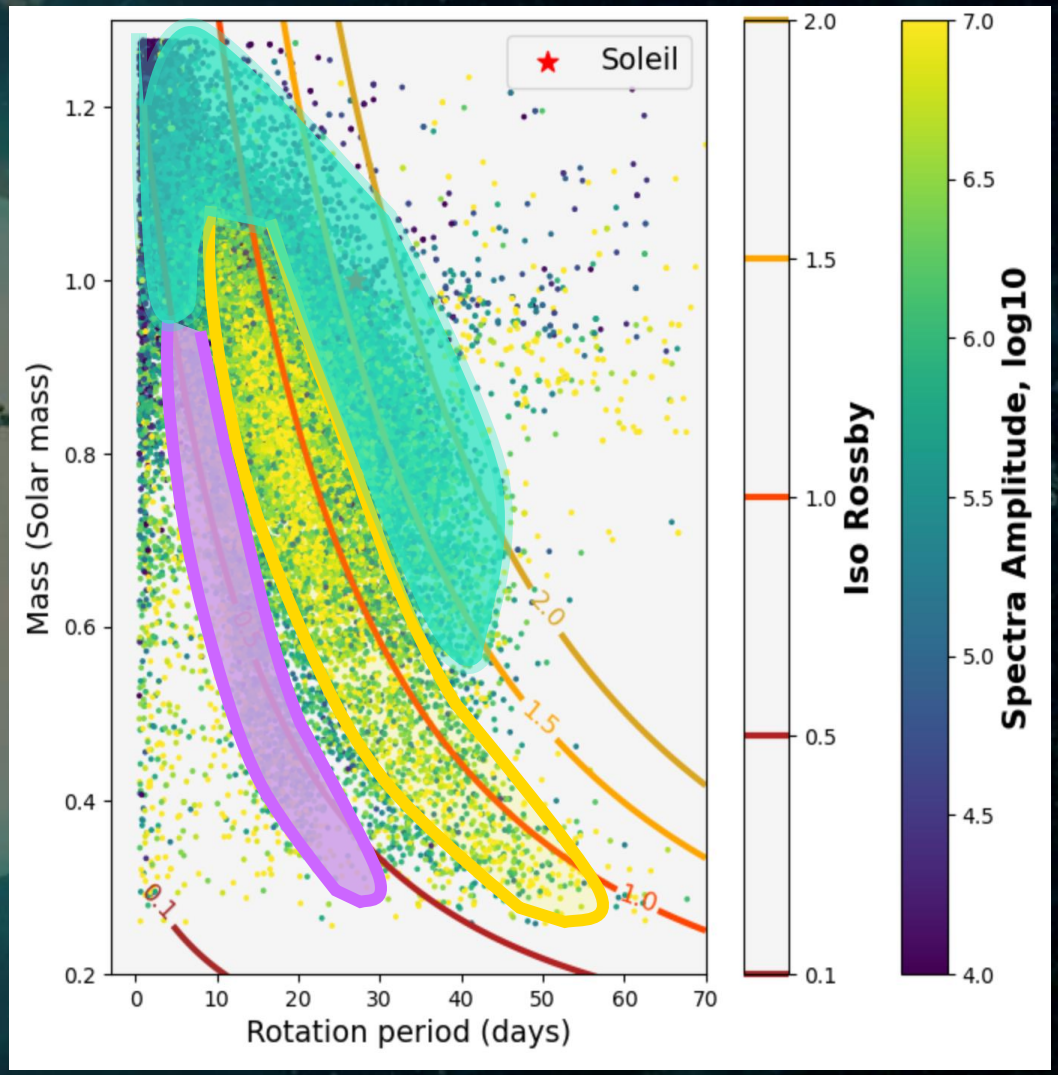
Long Spots : Spot lifetime > Rotation period

Short Spots : Spot lifetime < Rotation period

CONCLUSION

✓ **Three regimes of activity !**

- **Short spots and low surface coverage (Ro >1 and high mass stars)**
- **Long spots and low surface coverage (Ro <1)**
- **Long spots and hight surface coverage (Ro ≈ 1)**



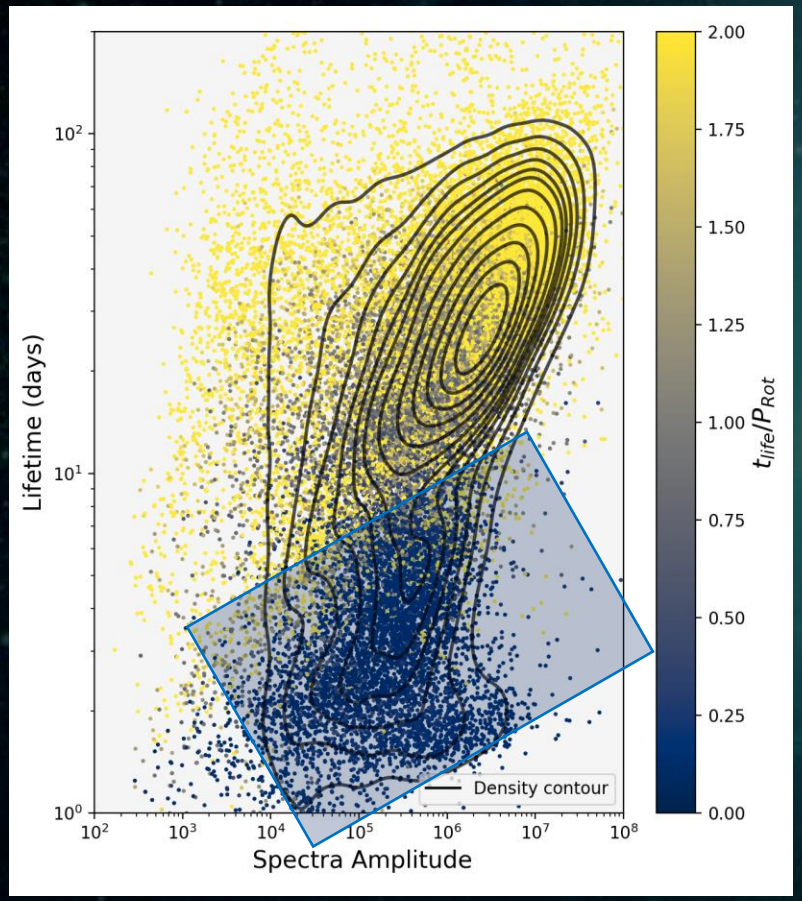
PERSPECTIVE

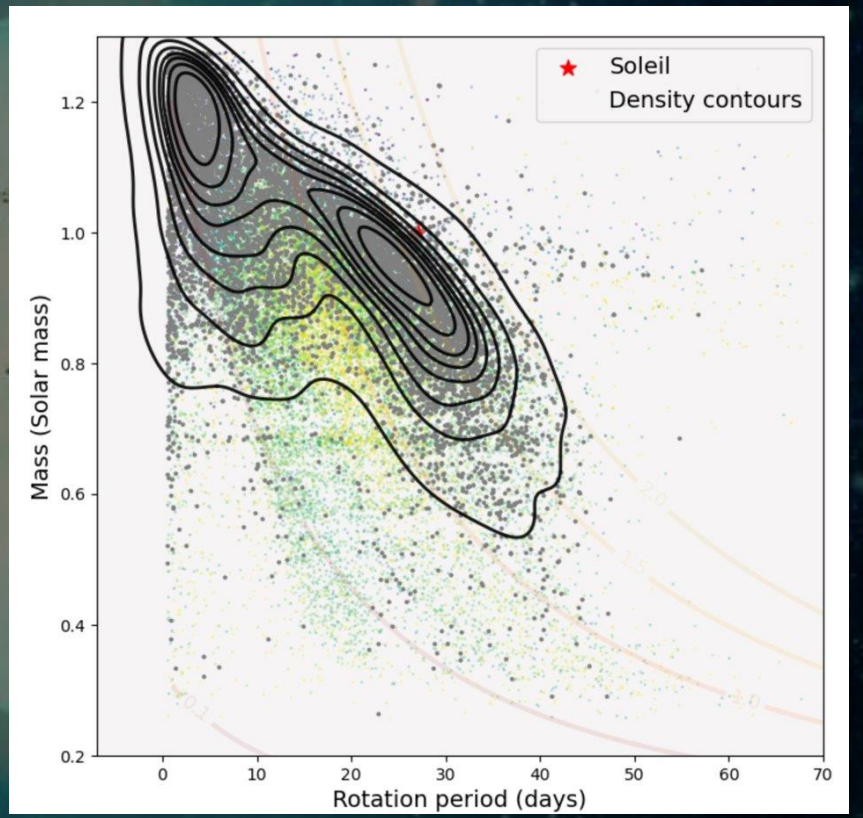
- Better understand the physical meaning of the spots lifetimes
- What does the different regime means in term od dynamo effects
- Understand the role of faculae
- Link with asteroseismology
- Impact of differential rotation

Link with numerical simulations


THANK YOU FOR
YOUR ATTENTION
!

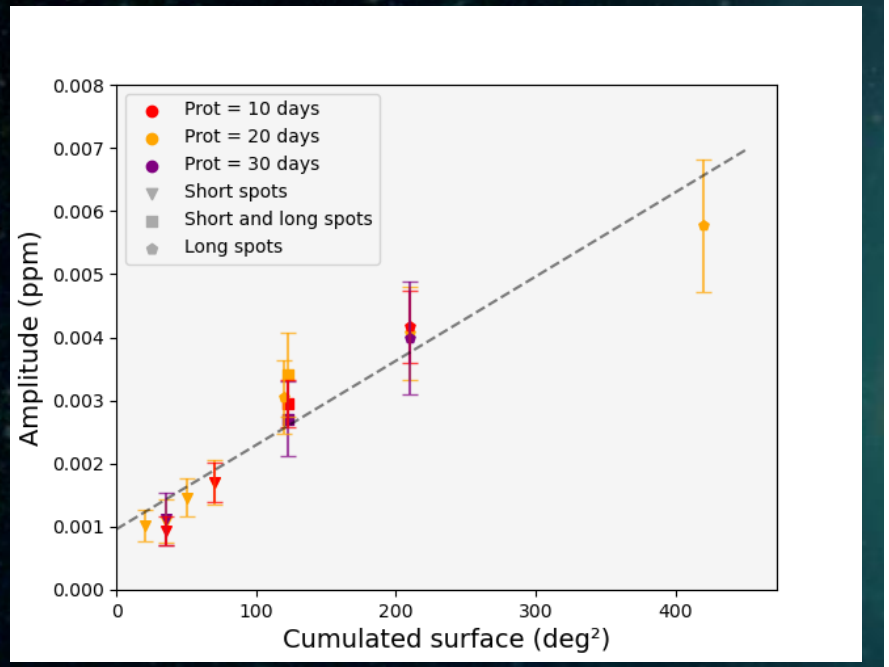
KEPLER DATA


Lifetime (days)
Spectra Amplitude
Density contour
t_{life}/P_{Rot}


Soleil
Density contours
Mass (Solar mass)
Rotation period (days)

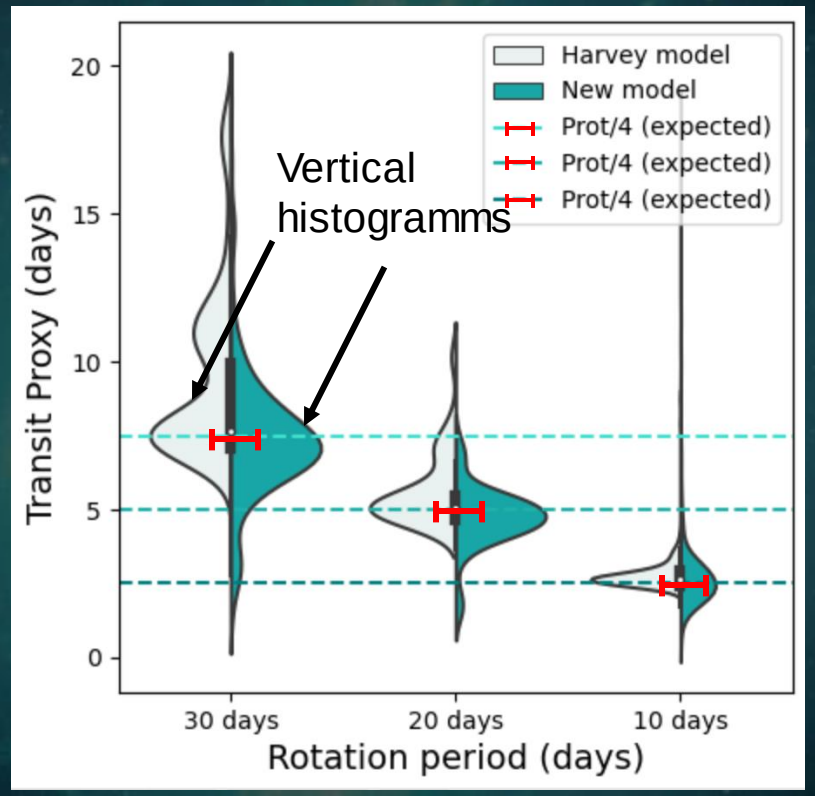
CONFIRMATION BY SIMULATIONS

Surface proxy



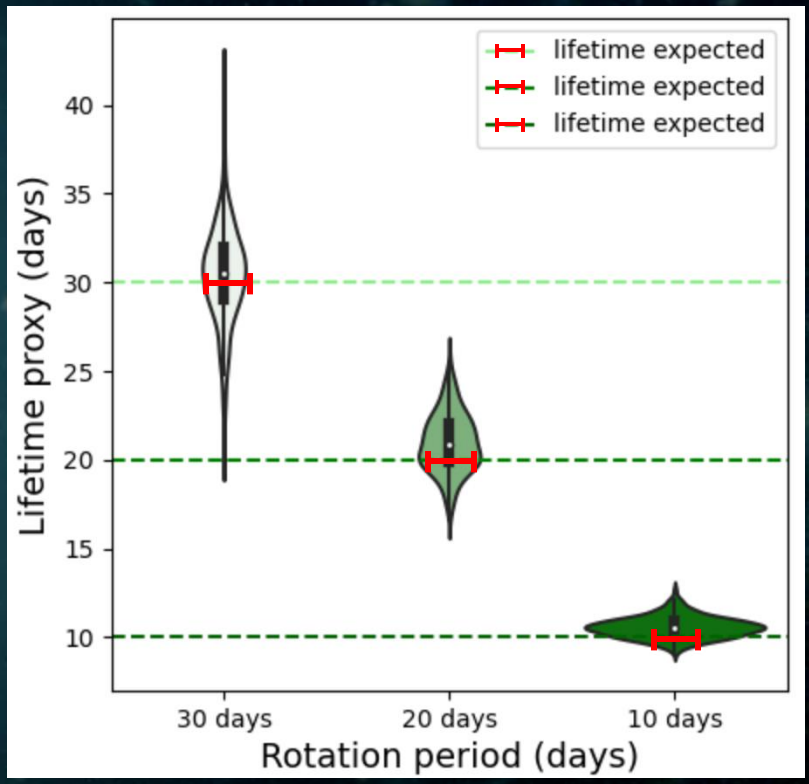
✓ Ampltide ∝ Cumulated Surface

Transit proxy



✓ The model finds the value of the transit time

Lifetime proxy



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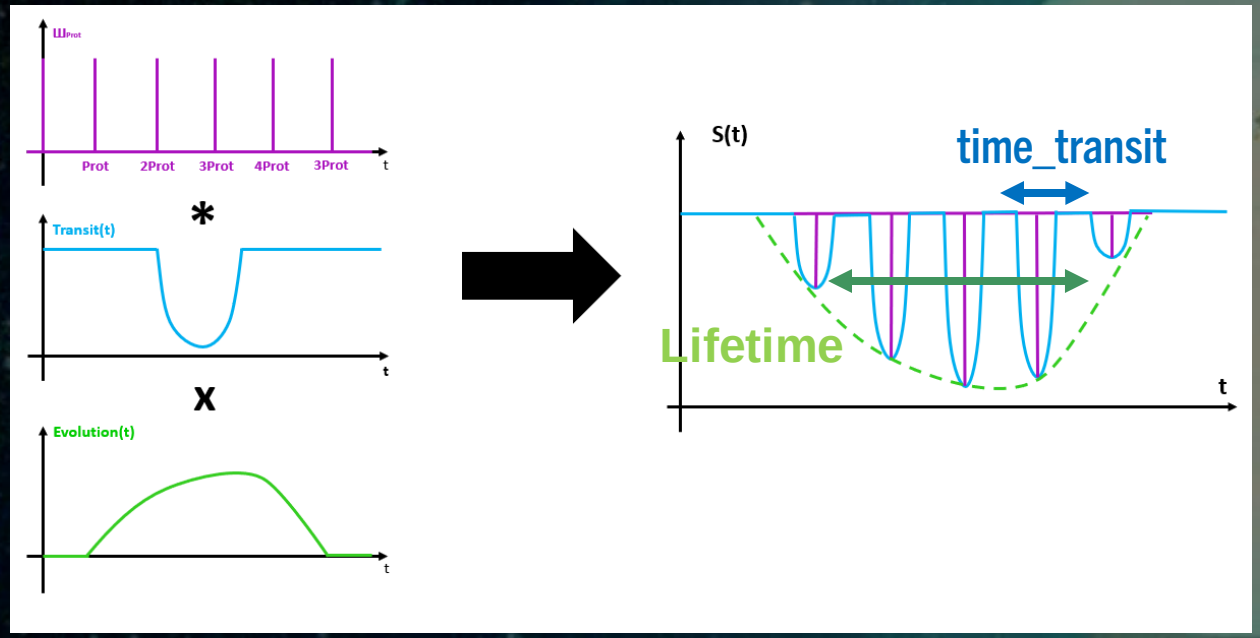
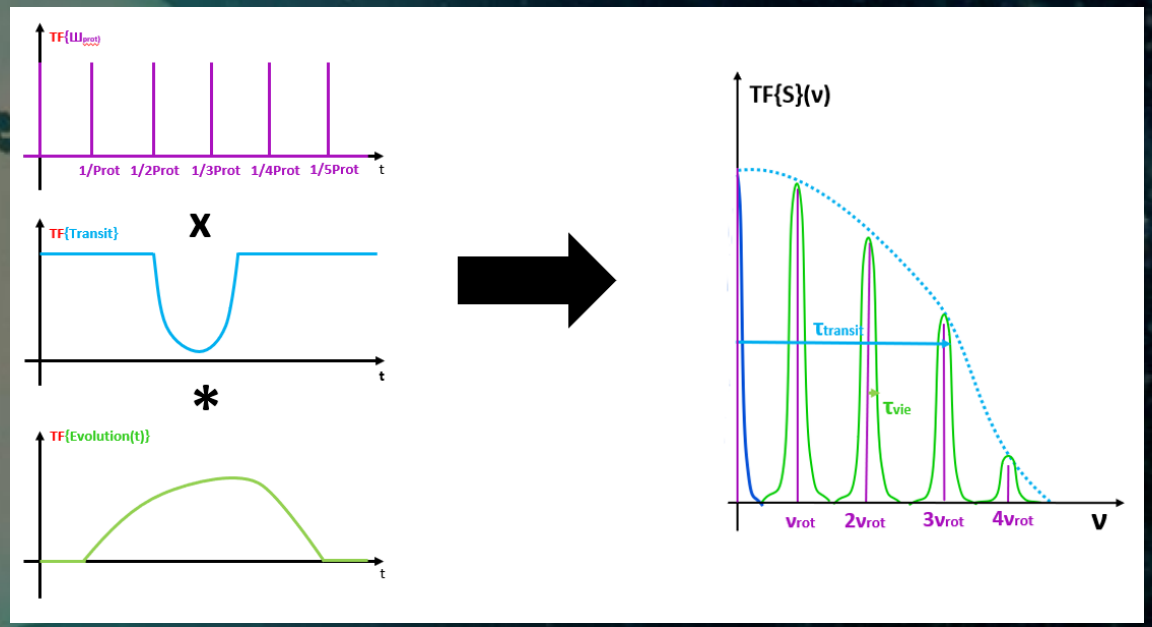
ANALYTICAL APPROACH

Temporal domain



Fourier domain



Two time information in a spot transit :

- The transit time (= Prot/2)
- The lifetime of the spot

METHOD

Two time i

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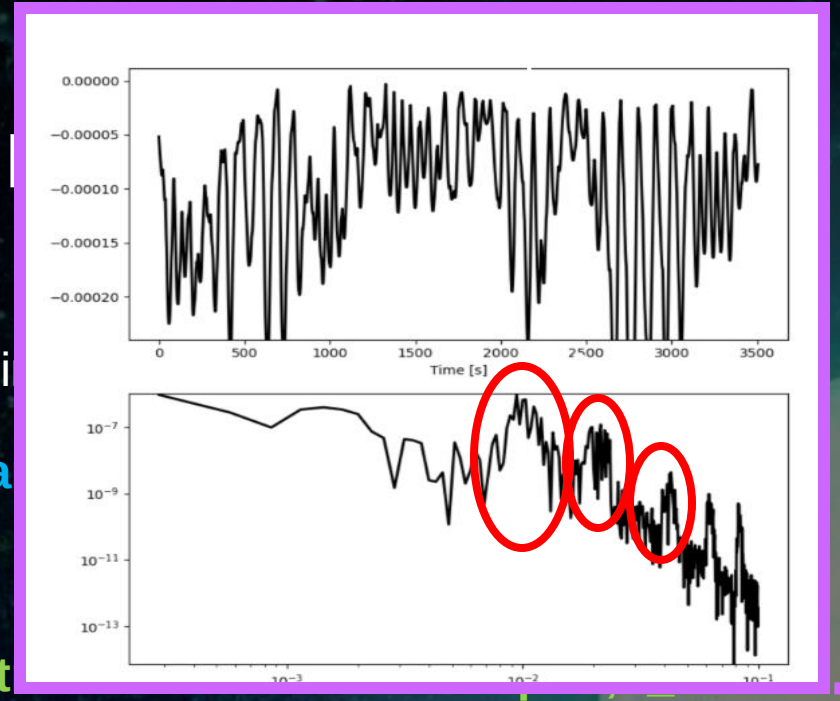
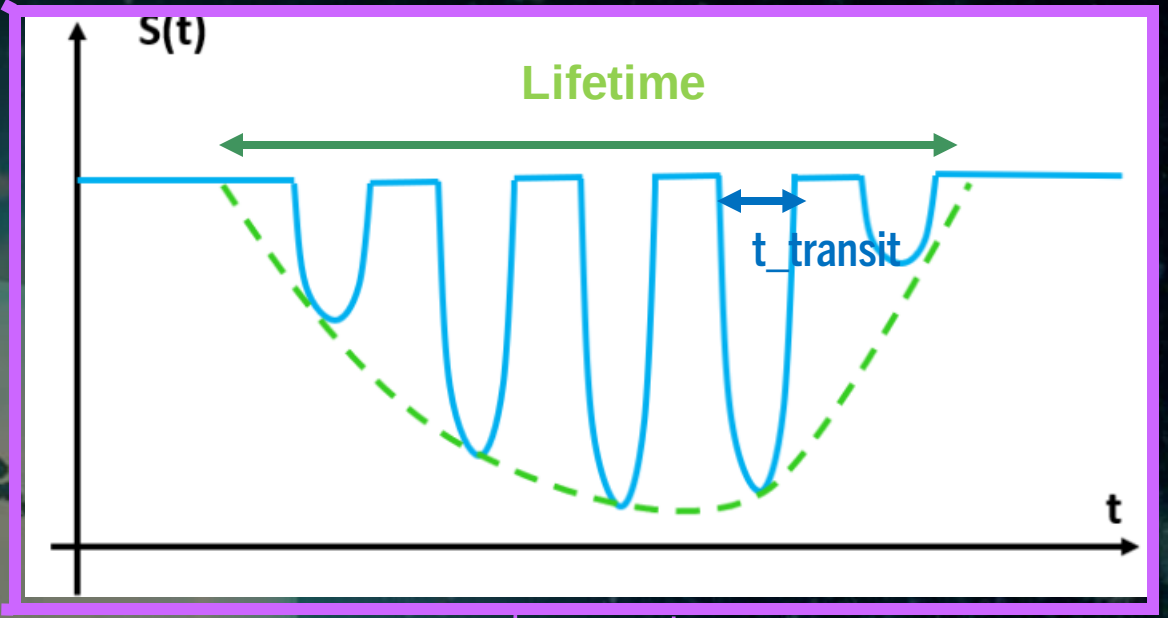
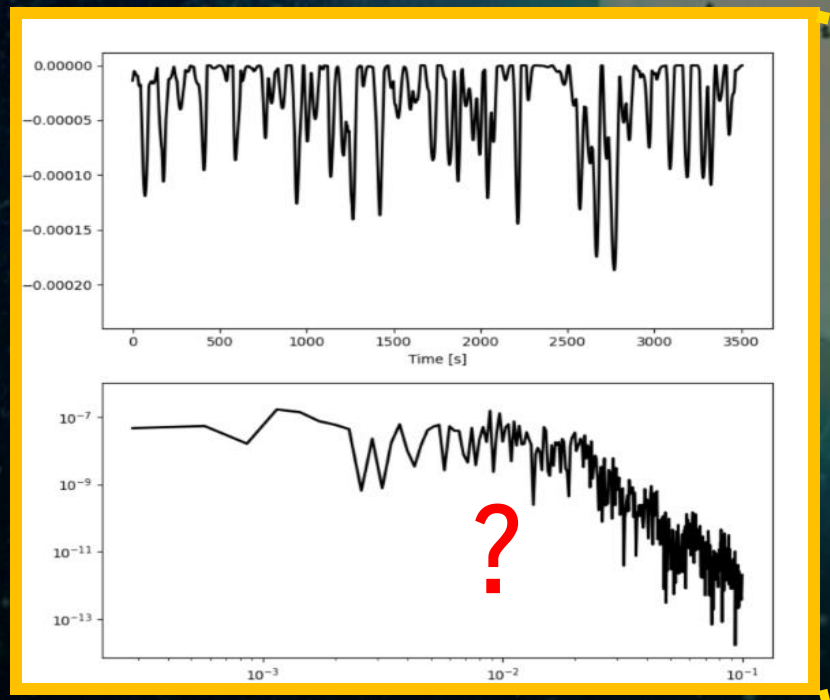
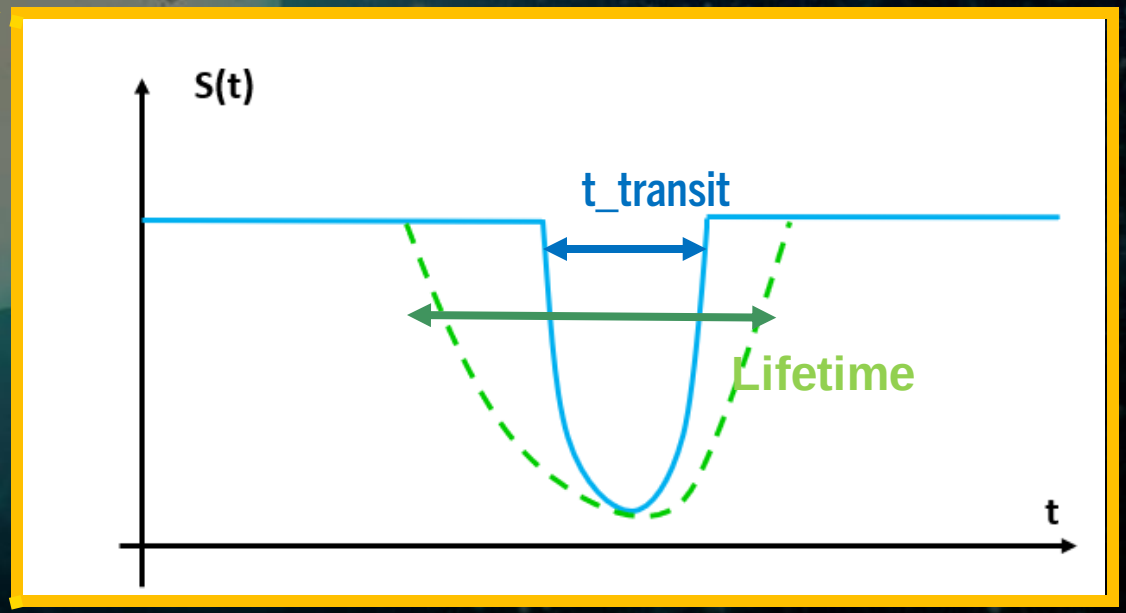
- **The int**





Exemple of the transit of one « long spot »





Exemple of the transit of one « short spot »